MAR 28 1925

Nos. 10-12. Vol. XVII. Oct.-Dec., 1924.

The ILLUMINATING ENGINEER

Edited by LEON GASTER

18/- Yearly. THE JOURNAL OF SCIENTIFIC ILLUMINATION 1/6 a Copy.

OFFICIAL ORGAN OF THE
Illuminating Engineering Society.
(Founded in London 1909.)

ILLUMINATING ENGINEERING PUBLISHING COMPANY, LTD.
32, VICTORIA STREET, LONDON, S.W.1
(TEL. No. VICTORIA 5215.)

Amongst other articles this number contains:

The Year's Progress in Illumination.

Some Problems in the Definition and Measurement of Illumination, by JULIUS FRITH, M.Sc.

Some Factors in Good Industrial Illumination, by D. R. WILSON.

Practical Illuminating Engineering, by A. L. POWELL.

Other matters dealt with include:

STAGE LIGHTING AND MUSIC—DECORATIVE AND THEATRICAL LIGHTING—THE DEVELOPMENT OF THE ELECTRIC INCANDESCENT LAMP, Etc.

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ELECTRICITY · ACETYLENE · OIL · GAS

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EDITORIAL.

The Year's Progress in Illuminating Engineering.

The record of progress in illuminating engineering, presented annually at the Convention of the American Illuminating Engineering Society, invariably makes interesting reading. From the report now available it appears that the last year was marked by steady progress rather than striking developments in illuminants. It is evident that the demand for light by the public is steadily growing. The consumption of tungsten filament lamps is stated to have reached the very high figure of 243,000,000 —an increase of 10 per cent. over the preceding year. It is also to be noted that the average light yielded per lamp sold has increased annually since 1907. It is somewhat remarkable to observe that over 100 million miniature lamps were produced, most of them for automobile lamps and "flashlight" torches. Work in connection with arc lamps and vapour lamps has been chiefly experimental. Yet it should not be assumed that these forms of lighting will ultimately be entirely superseded by incandescent electric lamps. There is always the possibility of some noteworthy advance that will bring them back into favour; while for decorative and spectacular effects such sources as the neon tubes have special opportunities.

In the report one misses similar comprehensive figures for gas lighting. If these could also be obtained in the future it would be a valuable addition. We notice, however, as an illustration of the recognition by the industry of the value of education, the establishment of a chair in gas engineering at the Johns Hopkins University.

In the field of street lighting many American cities seem to be making distinct advances. In some cases the available illumination in streets has been increased fivefold. Attempts have also been made to specify the requirements of different grades of streets in terms of "lumens per lamp per linear foot," or by mentioning the mounting height, spacing and illuminating power of sources to be employed. There is much to be said, from the scientific standpoint, for the method of classifying requirements of streets in terms of minimum horizontal illumination. Yet it is possible that, for the benefit of local authorities, some supplementary simpler and more easily applied method of stating requirements would be useful. Such a table would be a rough guide to the expenditure in lighting various classes of streets. The exact details of distribution of light, involving the choice of reflectors, etc., could afterwards be settled on the basis of ensuring the desired minimum illumination. Another feature of American developments has been the use of light as an aid to the direction of traffic. The New York tower system is being tried in Chicago, and it has been several times suggested that these methods of controlling traffic might be the subject of experiment in this country.

There are many other items that might be mentioned in passing. In cinematograph work the use of a concentrating mirror behind the carbons, as an alternative to the use of a condenser, appears to be yielding good results, and has contributed towards raising the efficiency—admittedly very low—of the optical system of the cinema lantern. Miners' lamps, which have been the subject of much study in this country, are also being experimented with in the United States. Efforts are being made to improve lighting conditions in schools, and a typical case in which the average illumination was increased from 1·2 to 4 foot-candles, is mentioned. Show-window lighting, motor-car headlights, and the lighting of railway carriages have also been the subject of experiment.

In connection with photometry, efforts to find a satisfactory primary standard of light are still continuing. Apparently the incandescent black body, maintained at a standard temperature, is still regarded as the most hopeful line of experiment. Integrating spheres are now being developed in a more compact and portable form. The photometric cell seems to be proving a useful adjunct in the laboratory, though there are various difficulties still to be overcome before it is likely to come into general use.

It is naturally impracticable to deal with the many and varied aspects of illumination touched on in this comprehensive report; in the abstract we present in pp. 149-153, it has only been possible to refer to some of the salient features. Looking through the report, one is inevitably struck by the considerable number of subjects that are being studied simultaneously in different countries. There never was a time when interchange of knowledge between experts was more to be desired. It is satisfactory to note that the broadening work of the International Illumination Commission, whose meeting in Geneva last July is the subject of reference in this report, is affording increasing opportunities for such international intercourse.

Sunlight and Health.

In referring to new forms of lamps and illuminants, we have frequently pointed out that their value should not be judged solely in terms of "efficiency" (output of visible light for a given consumption of energy). There are many qualities which may render illuminants valuable or the reverse, quite irrespective of efficiency thus defined. Many instances of such special qualities will occur—the striking orange-red colour of the neon light, and the presence of a strong ultra-violet element in the spectrum of the quartz tube mercury vapour are examples.

Some of these special qualities, though injurious if the illuminant is used without discretion, are very valuable if it is applied in a skilful and scientific manner. A good instance of this is to be found in the presence of a powerful ultra-violet constituent in the spectra of certain sources, such as some forms of arcs and the quartz tube mercury vapour lamp. These rays may give rise to injuries to vision unless suitable methods of screening are used, and adequate protection to the eyes is afforded. The inflammation of the eyes sometimes experienced by cinema artists and welding operators is caused in this way. But it is erroneous to assume that such rays are in all respects injurious and must be entirely eliminated. On the contrary, they may prove a valuable asset to health.

The beneficial effects of sunlight, to which the newly-formed Sunlight League is giving publicity, are believed to be associated largely with the presence of these rays. The smoke-laden atmosphere of industrial cities and the mists and fogs of winter check their passage. In the case of adults, the resultant loss of sunlight has a depressing effect. In the case of young children, it has been proved to be clearly associated with various "diseases of darkness" (rickets, tuberculosis, etc.), besides impeding the normal development of physique. Hence, when natural sunlight fails, recourse has been had to treatment with artificial light, now a regular feature at a number of hospitals and clinics. For this treatment sources of light specially rich in ultra-violet light are selected. But the exposure of the body to these rays is scientifically regulated to prevent excess, such as might irritate the skin, and the eyes of the patients, nurses and attendants are protected by special goggles against possible injury.

The research work of the past few years has brought to light many instances of the close relation between light and health. Sunlight has been found to be a valuable agent in the treatment of a number of diseases. It is also believed to have a valuable germicidal action, and its action is thus preventive as well as curative. A close relation has been shown to exist between the intensity of sunlight and the constitution of the blood; prolonged periods of dull weather and absence of the beneficent rays apparently prevent the formation of certain products indispensable to normal physical development. Strange to say, it is now believed that even our food is affected by the same agent. Vitamines unexposed to light lose part of their valuable properties.

No doubt some of these newly-discovered facts require verification and further study. But enough is known to justify the belief that the health, both of infants and adults, is closely associated with the presence of light.

We welcome, therefore, the activities of the Sunlight League in drawing public attention to this important subject, and we shall watch the development of its work with sympathy and interest.

The Effect of Light on Plant Growth.

A short time ago we referred to some recent experimental work in the United States on the above problem.* From these experiments the conclusion was drawn that, by supplementing daylight by artificial light comparable with daylight in intensity, the development of some plants could be considerably hastened. Thus it appeared that artificial light might prove a valuable means of producing rare fruits and flowers out of season, though the commercial possibilities of the process on a large scale need further investigation.

In a series of papers now presented on this subject in the Transactions of the American Illuminating Engineering Society † details of further research work, conducted chiefly at the Boyce Thompson Institute for Plant Research. A paper by Mr. H. W. Popp contains a useful survey of past experiments, and a bibliography, from which it may be seen that the problem is not exactly a new one, though it is now being studied by the aid of facilities for producing light vastly different from those enjoyed by earlier investigators.

It is known that light plays a part in the germination of some seeds, in the rate and habits of growth and development, in flowering and fruiting, in transpiration and evaporation of water from the plant, and in many other ways. The problem is thus an involved one, and it is further complicated by the individual peculiarities of plants, some of which thrive in full sunlight whilst some prefer partial shade. Garner and Allard in 1920 distinguished three classifications : (*a*) Plants responding to " long days " and blooming normally in midsummer, (*b*) " short day plants " blooming early in spring or late in autumn, and (*c*) other plants that respond to all lengths of day and bloom all the year round.

Yet another question is the effect of *quality*, as distinct from *quantity* of light. Mr. J. M. Arthur has found that the cutting off of ultra-violet light may result in somewhat earlier blooming. Mr. S. G. Hibben thinks it doubtful whether removal of these rays can be considered to have a generally beneficial effect on plant growth, but remarks that the removal of the long wave radiation is evidently detrimental. At present it would appear that a spectrum broadly similar to that of daylight will be found to have the best results. The whole question of the effect of light is, however, linked with effect of temperature and moisture and other factors that influence plant growth. From tests undertaken by Mr. V. A. Tiedjens, of the Massachusetts Agricultural Experiment Station, the general impression derived from the other experiments recently reported is confirmed. In some cases the length of the period from seedling to head formation and seed production was shortened by from two to four weeks, but care had to be exercised to ensure that the growth was favourable to good head formation.

There can be no doubt that we have here a very useful field for experiment. In some respects the investigation has much in common with researches on the effect of light on the human body. In both cases there is a large number of variable elements, and the effect of individual peculiarities must be borne in mind. One would like to see the problem taken up by horticulturists in this country.

LEON GASTER.

* ILLUM. ENG., May, 1924, p. 64.
† *Trans. Ill. Eng. Soc., U.S.A.*, December, 1924, pp. 981–1019.

THE YEAR'S PROGRESS IN ILLUMINATION.*

In the introduction to "The Year's Progress in Illumination," a review presented by the Committee on Progress of the American Illuminating Engineering Society, it is remarked that the past year has been a noteworthy one, on account of the meeting of the International Illumination Commission in Geneva, the Conferences at the British Empire Exhibition, and international developments generally.

Progress in Gas Lighting.

As usual the first section of the report is devoted to Progress in Gas Lighting. An important step has been the establishment at the Johns Hopkins University, of a chair in gas engineering. Whilst industrial gas courses have been given at other institutions the endowment of a professorship at the Johns Hopkins University is a permanent advance, and the results will be watched with interest.

It is recalled that at the end of 1923, 507 out of 709 British gas undertakings had applied for orders under the Gas Regulation Acts, permitting the declaration of low B.Th.U. standards. The average value adopted was 477 B.Th.U. The first State in America to afford gas companies a measure of freedom in heating value, similar to that granted in England, is Colorado. Agreement on a 600 B.Th.U. standard has been reached in Texas. The passage of the Gas Regulation Act in 1920 in England is regarded as marking the ultimate disappearance of the flat flame burner, and the discontinuation of tests of illuminating power by the L.C.C. this year records its official dismissal. In England attention has been devoted to securing a burner which is at once simple, cheap, scientific and efficient. The art of tinting and fashioning silica ware has been developed, and an increased use of this product in lighting is predicted.

In regard to candles few changes in design are to be noted, but a triangular section, with grooves down the flat sides, has been evolved with the object of giving a freer path to air flowing up towards the wick. In Germany lamps burning kerosene with a stated candle-power of 100 and a rate of consumption of one litre for 18 hours' burning have been put on the market. Incandescent lamps using kerosene vapour have also been developed.

Electric Incandescent Lamps.

In this field a striking development has been the development of commercial "tipless" lamp-bulbs. During the past year the demand for carbon filament lamps again dropped and less than 2,000,000 were sold. The consumption of tungsten filament lamps (exclusive of the miniature type) reached 243,000,000, an increase of roughly 10 per cent. This rate of advance has been maintained since 1907. During the same period the average light yielded by the lamps has increased 20 per cent. yearly. The average efficiency in 1923 attained 12·4 lumens per watt. The number of miniature lamps sold has also advanced to about 110,000,000—a growth of 30 per cent. as compared with the previous year. About 20 per cent. were sold for "flashlight" torches, and 65 per cent. for automobile lamps. In Russia factories at present cannot supply more than 15,000,000 lamps per annum. The life is stated to be 750 hours, and considerable difficulties in manufacture are reported. In Germany the number of lamps made has risen from 75,000,000 during the years 1911-13, to 135,000,000 during 1920-22. For the same period the production of carbon lamps has been reduced by half.

Arc and Vapour Lamps.

In this field there have been many experiments, but apparently few outstanding successes. Data have been obtained on the intrinsic brightness of

* Abstract of a Report presented at the Annual Convention of the *American Illuminating Engineering Society*. (Trans. Oct., 1924, Vol. XIX, No. 8.)

the arc-crater at different current densities, and values as high as 1,400 candles per sq. in. are reported. The best estimate of the temperature of the high intensity arc appears to be 4,700° C. but measurements on arcs burning under 80 atmospheres pressure give an absolute temperature of 8,600° abs. With an increase in pressure from 1·0 to 4·6 atmospheres the brightness of the crater was multiplied 3·48 times. Investigations have also been made on the tungsten arc. It is stated that the replacement of the polished spherical electrodes by a funnel with roughened surface and channelled scratches has proved beneficial. Attempts to improve the colour of vapour-tube sources continue. Promising results are recorded from a quartz tube vacuum lamp using an alloy of gallium and zinc, constructed by the Bureau of Standards. A "self-exhausting" type of mercury vapour lamp is stated to get over the difficulty of gradual deterioration of the vacuum. Various special applications of Neon lamps are mentioned—such as the use of the "flashing effect"—in measuring small capacities, and the use of Neon tubes as a detector of leaks from insulators on high voltage lines.

Projection Lamps.

Various minor improvements in flash-light lamps are recorded and it is mentioned that the London Police have been provided with a new portable lamp, which will yield light for ten hours without a charge, and may be adjusted to give either a wide or a concentrated beam. Another portable safety lantern is equipped with flexible folding legs. There have been many attempts to solve the "dazzle" problem in connection with motor-headlights. One ingenious form of dimming utilises an electric lamp containing two filaments, one unshielded, the other shielded by a semi-spherical metal cap. When the first filament is lighted, the headlamp gives the full driving light. When the current is switched to the shielded filament the cap cuts off the downward rays which would be reflected into the eyes of approaching drivers. The use of "spot lights" by motorists has been a frequent cause of glare; their use is prohibited in some districts. Tests on headlights for locomotives have shown the difficulty of making such measurements without suitable facilities and more detailed rules. An important question is the interval at which they should be cleaned so as to reduce to a minimum the effects of dust and dirt.

Modifications of the New York Tower traffic control system have been installed in Chicago. The installation of a number of powerful searchlights for lighthouse work is recorded. The revolving lens on Eclipse Island in South-West Australia is said to have a beam of 1,167,000 candlepower, with a range of 90 to 95 miles. Beacons on Long Island and South Bend (Indiana) are credited with five and four million candles respectively.

Miners' Lamps.

A combination oil and safety lamp for miners has been produced and is claimed to give a working light for 22 hours. Either illuminant is automatically extinguished when the other takes its place. Another lamp is designed to emit a musical note when 2 per cent. of harmful gases are present in the atmosphere. Canary-tinted glass has been used with miners' lamps and the colour is said to be beneficial in checking nystagmus. The report of the British Miners' Lamp Committee has issued a number of memoranda. It is agreed that the illumination furnished by miners' lamps is too low, and the possibility of securing higher illumination by means of fixed lamps is discussed.

Cinematograph Work.

Comparative tests have been made on cinematograph projectors employing a mirror instead of the condenser. With the arrangement adopted it was claimed that 51 per cent. of the light reflected from the mirror passed through the objective, as compared with 21 per cent. for lamps with condensers. Parabolic condenser lenses have also been produced and have facilitated greater utilisation of light and better control.

Street and Exterior Lighting.

Attention is drawn to the need for better lighting of highways outside the boundaries of cities. Out of nearly 500 replies from county engineers, only ten

stated that there was light provided for roads of this description. In cities the tendency is towards much higher intensities. Seven thoroughfares are mentioned in various cities, the illumination being increased from 6 to 18 times that provided by the superseded system. The Sub-Committee of the Pacific Coast Electric Association has given indications of mounting height, spacing, and illuminating power of sources in lumens, for parks, boulevards, secondary business and traffic thoroughfares, main business streets and "white ways." For the latter 10,000-25,000 lumens luminous arcs are suggested. Other reports make suggestions for lumens per lamp per linear foot for various types of thoroughfares. We see in these examples a tendency to classify illumination requirements in simple form. The Report also reviews progress in different sections of the United States, and contains some notes on developments in Great Britain and France.

Reference is made to the use of white bulb lamps in Marylebone, new electric units in the Charing Cross area, and the gas lighting of the Amusement Park at Wembley.

Many instances of display lighting are mentioned. Besides developments in America the lighting effects at Wembley and the "Searchlight Tattoo" given by the Royal Engineers at Aldershot are specially commended. For railway yards flood lighting systems seem to be gaining in favour. Out of 23 railway systems approached, 15 are using this system, or are about to do so. Units are mounted on towers up to 70 ft. high and 14 in. reflectors equipped with 1,000-watt lamps are installed. Examples of flood lighting of the faces of buildings are given, a feature being the use of colour-effects. A special opportunity for the use of exterior lighting is afforded by the petrol-supply stations which have been springing up rapidly. The growing use of artificial light to enable games and sports to be played at night is illustrated by the lighting of a football field in England, and by the successful illumination of tennis courts. Yet another instance of new developments in exterior lighting is provided by the night-illumination of market places, such as those at Aylesbury, Bedford and Long Eaton in this country.

Interior Lighting.

The Report covers a wide field under this heading. The semi-indirect lighting of the Welsh National Museum at Cardiff is quoted as an instance of developments in this country. In the United States the Post Office Department is making arrangements for the survey of existing buildings with a view to improvement. In the case of a large auditorium at Cleveland the method of lighting through diffusing glass panels in the roof has been adopted with good results. The absence of any apparent lighting units has a striking effect and the absence of glare is a good feature. Co-operation between architect and lighting engineers has resulted in the illumination of classrooms in twenty-two buildings in a midwest city being increased from 1·2 to 4 foot-candles. Data on the lighting of some theatres and cinemas are given. The mid-stage illumination in one case was 84 foot-candles. In picture theatres, both in England and America, there is a tendency to make more use of colour-effects. An interesting problem in America has been the applications of flood lighting in some of the famous caverns visited by sightseers.

For railway passenger cars in the United States a ceiling unit with enclosing opal bowl is coming into wider use. Recent tests of such a system showed 4·4 foot-candles on average seats, 5·8 in the aisle and an average of 4·6. A Sub-committee of the Pacific Coast Electric Association has issued a series of recommendations for stores, offices, etc. It is recommended that such buildings should be wired for 3 watts per sq. ft., to give a general illumination of approximately 15 foot-candles. A survey of shops in San Francisco showed that, out of 1,000, only 1 per cent. were considered properly lighted; 81 per cent. had insufficient illumination, 54 per cent. had obsolete fixtures, and 41 per cent. had wrongly placed and exposed lamps. Further tests on the "drawing power" of show-windows have been made. Certain windows were especially well lighted and it was found that 41 per cent. of persons passing stopped to

look at these. There has been a marked tendency towards higher illuminations in shop-windows. In one case the horizontal illumination was 90-150 foot-candles. The manager could survey the window from his desk, and by means of switches alter the conditions as desired. In restaurants methods of designing special lighting fittings to harmonise with the general scheme of decoration are being widely adopted.

In the field of industrial lighting attention is drawn to the activities of the Department of Labour in the State of Kentucky, which has issued a report recommending better conditions. Further tests on the effect of improved lighting on production are recorded. In one large factory improvements, involving an increase from 1·2 to 6·5 foot-candles, resulted in an increase in production of 13 per cent. A further increase in illumination to 9 foot-candles caused an improvement of 17·9 per cent. Another final increase in the candlepower of lamps led to 25·8 per cent. over the original production being realised.

Many advances in special types of fittings for different purposes are mentioned.

Photometry.

The applications of photometry are increasing. The Committee on Locomotive Headlights for the Association of Railway Electrical Engineers has formulated standard conditions for testing locomotive headlights. At the Reichasanstalt in Charlottenburg experiments have been made with small models, for the purpose of studying conditions of illumination in buildings. Researches suggest that increasing the field of view surrounding the visible photometric field leads to an appreciable increase in the accuracy of setting. Further investigations have been made on the possibility of using an incandescent black body at specified temperature. A research on the melting point of platinum, described in the Journal of the Franklin Institute, showed a brightness of 55·4 candles per sq. cm., with an estimated accuracy of 1/5 per cent. In this experiment a platinum cylinder was used as a black body, and was electrically heated.

The integrating sphere method of measuring coefficients of reflection has been adapted in apparatus of a portable form. In a modified form the instrument has been used to test the gloss on photographic papers.

The photo-electric cell has proved useful for the measurement of photographic densities, but requires great care in manipulation. Much work on colour-standardisation and spectro-photometry has been done at the National Physical Laboratory. A new instrument for measuring the "daylight factor" has been designed in the United States. Some new forms of flicker photometers have been designed and additional work comparing the results obtained with such instruments with those derived from photometers of the "equality of brightness" type has been done. Useful forms of auxiliary photometric apparatus for various purposes are described.

In a further section work on such subjects as luminescence, colour nomenclature systems, and various special effects of light is summarised. A study has been made of the effect on response of distribution of brightness in the visual field—a problem which has some practical bearing in cases when a worker is trying to see an object and his eye is at the same time conscious of surrounding adjacent surfaces of greater brightness. Attempts have been made to adjudicate the "glare" from various forms of headlights by observing the time taken to identify some pattern in a darkened room, after the eye had been exposed to the "glare." Formulæ showing the effect of size of object, and comparing intermittent and continuous exposure, have also been derived.

Illuminating Engineering.

In the final section under this heading attention is drawn to recent legislation and regulations on lighting. A code of lighting for factories and industrial workplaces has been prepared by the German Illuminating Engineering Society. Recommended values of illumination range from 0·5 to 2 hefner-lux, for roadways, passage ways, etc.; to 90-240 lux (7-20 foot-candles) for very fine work. A lighting code for industrial establishments also became effective in Massa-

chusetts on January 1st, 1924. Safety regulations for cinemas have been made by the Home Office in England. The German Illuminating Engineering Society has formulated rules for motor-car headlights. Electric lamps are limited to 35 watts, and between 20 and 35 watts the beam must strike the road at less than 15 metres distance.

Finally reference is made to the formation of an Illuminating Engineering Society in Austria, and to the proceedings of the International Illumination Commission in Geneva.

SOME FACTORS IN GOOD INDUSTRIAL LIGHTING.*

By D. R. WILSON.

(*Secretary of the Industrial Fatigue Research Board.*)

IN a paper on the above subject, read by Mr. D. R. Wilson at the Liverpool Congress of the Royal Institute of Public Health, it was remarked that the recognition of lighting as an important factor in industrial hygiene has been of comparatively recent growth. But during the last few years greater attention has been paid to the subject, and this has been fostered by the striking progress made on the technical side of illuminating engineering. Mr. Wilson then went on to recall the work of the Home Office Departmental Committee on Lighting in Factories and Workshops. It is now accepted firstly, that accidents may be caused by bad lighting—either through insufficiency of illumination or by the presence of imperfectly shaded lights in the field of vision; secondly, that both quantity and quality of output are dependent on the provision of good lighting; and, thirdly, that good lighting is not only itself an important factor in the preservation of health, but acts as a detector of dirt and refuse, which are such cogent influences in making premises unhygienic.

After giving an explanation of the chief terms used in illuminating engineering, Mr. Wilson explained the operation of the usual types of illumination-photometers, which have played such an important part in the study of industrial lighting.

Good lighting, he pointed out, must be both "adequate" and "suitable." As regards adequacy the Home Office Committee has suggested a minimum of five foot-candles for very fine processes, and three foot-candles for fine processes, while 0·25 foot-candles has been recommended as the minimum for general lighting, apart from the actual illumination of the work. Great importance is to be attached to regular maintenance and cleaning. Half the possible light may easily be lost through dirty globes, defective gas mantles, etc.; since all sources and decorations obviously cannot be kept in their original state of efficiency, the initial standard of illumination should be considerably higher than that ultimately aimed at.

As regards "suitability" the great majority of factories are capable of improvement. Mr. Wilson distinguished three forms of glare, that due to looking directly at a bright source of light; that due to the reflection into the eye of light from polished material, and the most common form of glare, due to the mere presence of a bright source near the line of vision, light entering the eye obliquely. Remedies may take the form of suitable screens, or careful placing of lights. Shading by translucent material has the advantage over complete screening in that it affords some general, as well as local lighting; however, translucent glass shades are easily broken, whereas opaque metal screens are not. Mr. Wilson explained in some detail how the recommendations of the Home Office Committee in regard to avoidance of glare could most easily be met.

Shadows, like glare, depend to a great extent both on position of lights

* Abstract of a paper read before the Liverpool Congress of the Royal Sanitary Institute.

and shading. The simplest remedy for unduly sharp shadows is efficient shading, but it is clear that correct positions for light-sources are equally important. As an instance, Mr. Wilson mentioned that he had frequently seen compositors working in their own shadows, cast on the cases by some lamp intended to illuminate a neighbouring frame.

In conclusion, Mr. Wilson said that though he had seen many admirable examples of installations designed by industrial firms themselves, he had also often been in factories where every canon of good lighting had been broken, simply owing to want of thought—for instance, the use of shallow conical covers (relics of old carbon filament lamp days which ought to be completely abolished) instead of scientifically designed shades, wrong spacing of the points relative to plant, and many other faults.

He concluded: "I submit, therefore, that whenever a system of lighting is about to be installed in a factory, expert advice should, as a rule, be sought before the work is begun, and that before it is completed the employer should satisfy himself by actual experiment in the way of adjustment that the best conditions have been attained. . . . I would like to emphasise the way in which lighting differs fundamentally from other factors in the workers' environment, as this has an important bearing on the special difficulties inherent in the study of illumination. In the case of temperature and ventilation, convection and diffusion come into play, and we can safely say that the conditions at any point are approximately reproduced at any neighbouring point. In lighting this is not so. Light travels irresistibly in straight lines, and so it is often possible to find conditions entirely different as between one point and another a few inches removed from it."

THE DEVELOPMENT OF THE ELECTRIC INCANDESCENT LAMP.

A USEFUL contribution by Messrs. B. P. Dudding and C. J. Smithells to the *Beama Journal* contains an exposition of physical principles underlying the efficiency of filaments of electric incandescent lamps. After summarising the laws of radiation, illustrated by diagrams tracing the effect of temperature on the percentage of radiation emitted in a visible form, the authors discuss the choice of materials. A diagram for untreated and treated carbon, tungsten and osmium illustrates clearly the influence of selective radiation. Yet it is pointed out that the choice of material depends much more on the temperature of incandescence it can withstand than on these selective qualities. Platinum, osmium, iridium, etc., are considered in turn and a few words are said on the "Helion" filament utilising a combination of silicon and carbon. It would appear that promising results were obtained in this way; but for the advent of the tungsten filament, developments in the direction of utilising silicon carbide would doubtless have proceeded. The latter portion of the contribution deals with the properties of tungsten and gasfilled lamps. In conclusion a table showing stages of progress from the carbon filament of 1903 consuming 4·5-5 watts per candle, to the gas-filled lamp of 1923, with an efficiency estimated at almost exactly five times as great.

SOME PROBLEMS IN THE DEFINITION AND MEASUREMENT OF ILLUMINATION.

By JULIUS FRITH, M.Sc., M.I.E.E.

THE present state of the science of illumination is not wholly satisfactory, and this from two separate causes.

The first is that the units usually employed are, in a sense, unscientific; the definitions used for flux and the lumen seem to involve an idea of time, for which, however, they leave no place: if a lumen is defined as the "quantity of light" received by a square foot of surface one foot away from a light source of a candlepower one is inevitably but quite unnecessarily led to ask, in what time?

This physiological aspect of the question must, therefore, not be lost sight of. Under the present chaotic methods in vogue, each individual may lay claim to a different treatment of the science of illumination, and just as one individual's eye may differ from another (as for instance in colour perception) so it is more than likely that the average vision of the individuals of one nation may differ from those of another nation.

How, then, are we to emerge from this difficulty? Any standards set up with reference to one eye or even to the

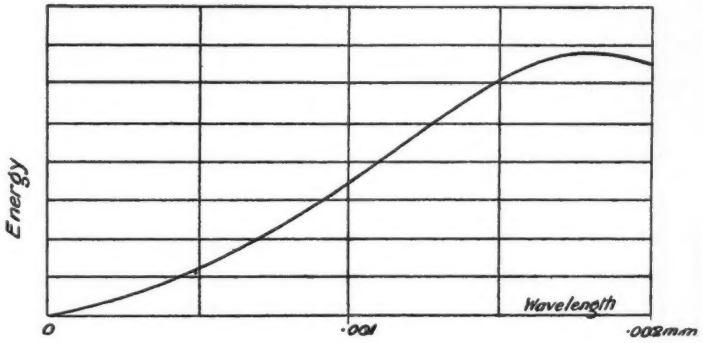

Fig. 1.

The second difficulty is one of much more subtlety, as it involves that bugbear of scientific measurement the confusion between the physical and the physiological. This is best illustrated by the assertion of certain schools of philosophy that an uninhabited island remains in absolute darkness and silence till it bursts into sound and colour on the advent of the first ear and eye.

In the subject under discussion there is just sufficient truth in this point of view to make it confusing, in that the whole science of illumination exists primarily to make suitable impressions on the human eye and is to that extent dependent on the limitations and individual variations of that organ.

average of the eyes of one nation or generation, conceiving such a thing to be possible, might not be true for another nation or a succeeding generation.

Let us turn first to physical science and see what help this can give us. Let us take that unattained ideal, the standard candle. The physicist can, by means of a spectroscope, spread out the radiation from this and arrange it in order of wavelength; he can then measure the energy represented by the rays of each wavelength and plot a curve something like Fig. 1, making due allowance for the selective absorption of the prism or grating and of any lenses used in his spectroscope.

Having assumed a standard candle, it is

only one more strain on our imagination to suppose a standard eye. The physiologist can experiment on this eye, presumably his own, and, though with somewhat less exactitude than the physicist, draw a curve (Fig. 2) representing the effect on this eye of *equal* amounts of energy over the same range of wavelength.

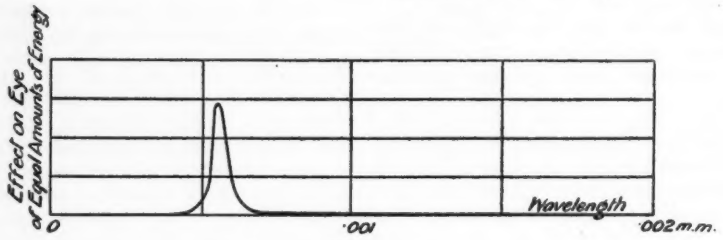

Fig. 2.

On comparing this curve obtained for the standard eye with other individual eyes we should, however, find even more divergence than the physicist would find amongst standard candles.

Those eyes which gave results which differed too much from the curve we could call colour-blind and defective, but the divergence amongst individuals would still be very great though a mean curve might be drawn for, say, the British nation, which curve would almost certainly differ from the mean of, say, an equatorial or arctic nation (or even our own nation a dozen years hence).

Individual differences could probably be grouped as between young and old, and possibly between individuals according to the colour of their eyes.

Immense difficulties would certainly be experienced due to the psychological differences in individuals involving the impossibility of knowing the effect produced except by their own account of it.

Assuming now the possession of the two curves (Figs. 1 and 2), what use can be made of them ? The first thing to do is to combine them as in Fig. 3. Then to multiply the ordinates of the two curves together : this gives us a curve of the radiation of the standard candle in terms of usefulness for the purpose of illumination. The result of this is given in the full line curve in Fig. 3.

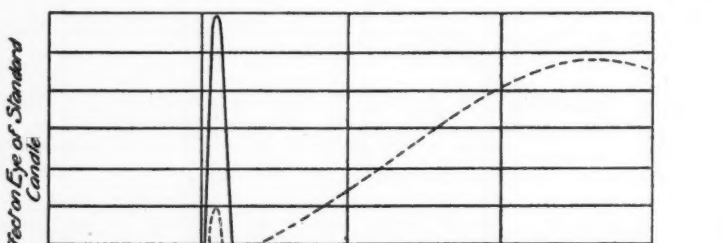

Fig. 3.

It might be a fair assumption that the *area* under this curve is a measure of the usefulness for illuminating purposes of this particular light source. Any other light source might be treated in the same way and its illuminating power compared with the standard.

Now it will be evident that this is

quite different from what is described in the text books as the measurement of the candlepower of a light source. Nearly all the photometers employed in practice are made so as to illuminate part of the field of vision, the other part being illuminated by a standard light source, and the eye of the observer is made to perform what is virtually the function of the curve in Fig. 2.

All these photometers, therefore, depend not only on the particular eye employed being sufficiently normal to be representative, but also on the power of that eye to judge illumination apart from colour, a process which must depend much more on the personal equation than even the making of a Fig. 2 curve, as the eye may be suffering from fatigue for one colour range and not for the other.

It is seen, therefore, how very unsatisfactory are the accepted methods of measurements of illumination, and how one is forced to look for some others which may be immune to such damaging criticism. The curve (Fig. 1) is an energy curve obtained by, say, a bolometer, which absorbs all the radiation, visible and invisible, on a blackened platinum strip turning it into heat, which is measured in some indirect way, usually electrical.

A radiometer such as one sees in an optician's shop window in which a mica vane is driven round by the energy on a beam of light, might be used, if provided with a suitable screen transparent to visible radiation only and that in the porportion to its effect on the eye. Such an apparatus combined with a tachometer might be made direct reading in illumination units.

A more promising but infinitely more difficult solution would be the imitation of the human eye itself with a galvanometer in place of the brain.

Let us turn from the physicist and see what the chemist has to offer. There are several chemical combinations brought about by the action of light which might be used; there is the reduction of silver salts as used in photography, and there is the formation of chlorofil. By patient research some such chemical action might be discovered, the amount of which in a given time would form a measure of the illuminating power of the light to which it had been subjected. One fears, however, that the ultra-violet energy which is invisible to ordinary eyes would always tend to be the most chemically active.

It was seen from the foregoing how very difficult it is to fix a light standard in terms of the human eye. A slightly different angle of attack would be to say that the human eye has been developed to use sunlight to the best advantage and therefore a standard of illumination based on sunlight should be acceptable to human beings.

The first difficulty encountered in carrying this into effect is the very variable nature of sunlight as delivered to us. To the dweller in Salford sunlight must have a very different meaning from that conveyed to the native of India.

This difference, however, is not due so much to the sun as to the atmosphere through which it is invited to reach us, and the standard might be fixed in terms of the sunlight received by, say, the Blick observatory. This might incidentally give our city folk an ideal to live up to which would help forward the good work of the smoke abaters.

Standard illumination might then be defined as that of a slab of plaster of Paris exposed normal to the sun's rays at 12 noon; taking the average of every Sunday in the year and rejecting any reading which differed by more than 10 per cent. from the average.

Substandards could then be made and distributed. These substandards should be made to give light of exactly the same colour as the standard. This can be arranged by suitable screens.

The commercial measurement of approximate candlepowers would have to be made from these substandards using the mean of several, presumably normal, eyes.

The primary standard would thus be one of illumination, leaving the candlepower to be a derived unit from this, and being numerically equal to the illumination produced on a similar plaster of Paris slab one foot from the light source and normal to it, the law of inverse squares holding.

After this, considerable care is required in defining the further units or confusion is likely to occur, as for instance in the badly-worded definition of the lumen

already quoted. The term " quantity of light " must be avoided for the reason there stated.

The whole idea involved in the " lumen " might with advantage be jetsonised, as although undoubtedly convenient, it has the further disadvantage of dragging in 4π which really can very well be done without. Some teachers love it as it gives an opportunity of enlarging on the area of a sphere which again does not really enter the arena of practical illumination.

As to the naming of the units, the candlepower for sources of light and the foot-candle for illumination have come to stay and are not at all bad, forming as they do in company with the volt, ampere and ohm a pleasant link with the past.

The brightness of a surface depends not only on its illumination but on the nature of the surface. No surface gives back all of the light which falls on it. Some is absorbed and turned into heat, some is transmitted through the material, some may be used to produce chemical changes in the material or to permit certain changes that can only take place in the light.

Some of the light is reflected from the surface and renders the object visible to the eye, objects can on the other hand be rendered visible by inference by not reflecting any light, as black printing on white paper.

Reflection may take place by merely changing the direction of the ray of light as a whole, as by a plane mirror, or changing it in some definite manner as by a concave or convex mirror, or by scattering it about equally in all directions which results from reflection from a great number of small facets irregularly placed all over the surface, as for instance from a piece of loaf sugar, or on a small scale any matt white surface. The two types of reflection can go on simultaneously as from a very smooth but not glazed white paper.

Some surfaces called " white " have the power of reflecting all the wave-lengths equally, others called " coloured " have the still more curious power of absorbing some of the wave-lengths and reflecting others. As far as we know a surface never " colours " light ; it can only exhibit its own peculiar colour if the light falling on it happens to contain that particular wave-length, otherwise it appears black.

Some surfaces appear to be able to exhibit their colour only by scattered light, and reflect all the wave-lengths when behaving as mirrors. For example, a polished mahogany chair appears in general of a rich red colour, but those parts from which light is regularly reflected, observing the rules of reflection as it were, appear white. This shows that the absorbing power of a surface is limited and that it can be flooded by enough white light to mask the colour effect. In some cases this may be accentuated by the glaze or polish acting as a colourless reflector. On the other hand a reflector of polished copper or gold reflects red or yellow light.

Colour vision is a good example of the impossibility of treating illumination as a purely physical science. For instance, an impression of green which is almost indistinguishable from the monochromatic green of the spectrum can be produced on the eye by printing a sufficiently fine stipple of alternately blue and yellow dots.

The light from these coloured dots does not combine in any physical way outside the eye and can be readily separated out by a prism. The two rays of different wave-lengths enter the eye and there, either by simultaneously exciting the blue and yellow optic nerves, or by some other mechanism, produce the same effect as a monochromatic green light of quite another wave-length.

From the point of view of physics the two phenomena have nothing in common.

Paints and pigments may either be a mechanical mixture of substances giving different wave-lengths, arranged side by side by the paint brush and capable, in theory at least, of being picked out and separated again under the microscope, or they may be composed of a single substance having the power of reflecting waves of one small range of wave-lengths. And there may be two pigments, one in each of these two quite different classes, both giving the same colour impression.

The wonder is that in nature there are so many substances which absorb all the components of white light except one particular wave-length which they reflect, *i.e.*, that there are so many "primary colours" in nature. This is due to the particles forming the substance having a natural time of vibration equivalent to these particular wave-lengths; as each string of a piano has one note which it prefers to emit.

Just as pigments reflect light of one wave-length so glasses transmit light of one wave-length only, but the process of combining them is different; glasses are generally put in series, pigments in parallel. Two glasses in series transmit only that wave-length for which they have a common permeability. A yellow and blue glass in series do not produce green but black.

Many substances behave differently by transmitted than by reflected light. Copper is green by the first and red by the latter. This does not happen for a coloured solution, however.

The *brightness* of a surface which is not itself a source of light is the illumination of the surface multiplied by the "coefficient of reflection." The brightness of a surface which is itself the source of light is the reciprocal to the number of square feet of the surfaces which are required to produce one candlepower. That these two definitions are really the same is seen by the following argument: An illumination of one foot-candle is produced on a surface of one square foot by placing it one foot from a source of one candlepower. Let the coefficient of reflection be unity, the concentrated light from this square foot of surface would be equivalent to one candlepower just as if its brightness were due to itself alone.

The rest of the science of illumination consists of two processes: studying the action of various shades and reflectors, not at all the least important in the latter class are the walls and ceilings of rooms, and the calculation of the illuminating effect of one or more light sources on various surfaces, generally either the surface of a table or bench or that of a roadway. These calculations are of very simple character and involve practically nothing but the law of inverse squares (which, by the way, is almost nullified by reflection from walls, etc.) and the application of the cosines of the various angles involved.

The lines of progress will be concerned with getting plenty of scattered light into the eye from the objects on which one's attention is fixed, just enough light from other adjacent objects to prevent accidents and the total exclusion from the eye of light direct from the light source and of direct reflected light from any object.

THE ACCURACY OF ILLUMINATION-PHOTOMETERS.

IT would probably be admitted by most people who have occasion to use photometric instruments, that one does well if with the ordinary form of portable photometer, one can rely on getting results correct to within ± 10 per cent. This may seem a big margin. But it must be remembered that photometry is unlike most other forms of physical measurement, in that it introduces the personal peculiarities of the observer.

Assuming, moreover, that the instrument itself is dead-accurate, there arises the question whether the standard from which it is calibrated is exact. Not everyone can arrange to send their instrument to the N.P.L. where it can be checked with precision. If one was to make a survey of the substandards in use at various laboratories in London one might find considerable variations.

Lastly, there are possibilities of variations due to the way in which the instrument is used. There may be a certain amount of polished reflection off the photometric surface or test-plate. Another point less frequently appreciated is the effect of obscuration of light by the observer's body. Shadows are evident when there are distributed direct light-sources; yet it is not always easy to avoid them. When a room is lighted indirectly the shadows may be so soft as to be almost inappreciable to the eye; and yet their presence may make a great difference to the photometric reading.

STAGE LIGHTING IN CONNECTION WITH MUSIC.

By Miss MARY WURM.

IN THE ILLUMINATING ENGINEER of May, 1919, I find the following interesting passage (taken from the paper read by Mr. B. Fagan): "The day is not far off when we shall see the electrician an artist as well as a technical expert, seated at his switchboard like a player at an organ, sending forth rhythmic harmonies of light that shall be as music to the eyes, swaying strange subconscious moods in the audience, in perfect tune with the unfolding of the drama in which he himself is playing a part of no mean importance." And again: "In Germany stage lighting is head and shoulders above the rest of the world. This is a fact that might make us think." Since Mr. Fagan's paper in 1919, I happen to know that Mr. Basil Dean, about two years ago, had the famous Lighting Director of the Dresden Grand Opera House, Mr. Hasait, come over here, and this meant not only Mr. Dean's great interest in the matter of stage lighting, but his desire of getting hold of the very newest and best stage-lighting effects possible.

At that time I was acting as solo-rehearser (coach or *correpetiteur*) at the Dresden Opera. I had also the duties of a sub-conductor—behind the scenes. I was glad of the opportunity of gaining more experience whilst waiting for the performance at Leipzig of my own Grand Opera. (It was brought out there in 1922.) My duties at Dresden were, amongst others, to carry out the written instructions of Mr. Hasait, in conveying to his operators the exact moment at which certain lighting effects were required. This—especially in Wagner's works, more so in new works performed for the first time—meant a great responsibility, but always expected from conductor-students. In my case—being the first woman ever employed in such a capacity at Dresden, certainly for the first time in Germany—meant double responsibility.

With the exception of at Bayreuth, and possibly also at Munich, I do not think that any opera house gives, as in Dresden, such minute attention to lighting effects in connection with the special musical themes. Stage-lighting is to-day both a craft and an art assuming immense importance, it therefore requires the co-operation of real artistic experts. In the case of Opera, there is, of course, a mingling of all forms of art. When one thinks of what technical difficulties have often to be overcome with intricate scenic arrangements, one must have the profoundest admiration for the illuminating engineer, who understands his work, for lighting must be used as an embodiment of emotion.

It seems that in England the illuminating engineer is still often called in for consultation almost at the last minute. At Dresden he and the musical stage-manager co-operate together. When a new opera is to be brought out, the musical conductor receives the orchestral score and a pianoforte score. His conductor-students also receive pianoforte scores. The stage-manager receives his copy, between each musical page of which is a plain sheet of paper on to which he makes his drawings and special entries. The lighting director also receives a pianoforte score (at Dresden, Mr. Hasait is also answerable for the scenery painting) into which he has, after careful study, written all sorts of pencil marks. This after hours of collaboration with the chief stage-manager, Herr Georg Toller, himself once a famous opera singer. As it is not to be expected of the actual lighting operators who are intelligent, but simple workmen, that they should understand musical signs, the conductor-student is called in, and as I stated before, has now the responsibility of giving the commands, the workmen having small books into which all sorts of "numbers" relating to their "plants" is written. It would be going into too

many details here were I to divulge all the lighting devices, besides, I do not profess to be anything but just a sensitive musician. Let it be said, however, that at Dresden, for instance, many "lighting" rehearsals, with and without music, take place when a new opera is brought out. But even for the old ones —rehearsals are required. Nearly all Wagner's operas are rehearsed each time they are performed, even if performances follow each other with only a few days between. But then watch the result. What can be more beautiful than the "Karfreitag-Zauber" in "Parsifal"?

If there ever is a chance of a National Opera—an everyday opera for the people here—let the best illuminating engineers be engaged, for without these no success could be anticipated. As is well known, colour in nature and in art can give pleasure or pain. There are operas on which to a great extent the success depends on the proper lighting system, such an opera is, for instance, the modern one "Ikdar" by Mraczek. Richard Strauss's operas are not so intricate as Wagner's—it is amusing to read that in 1611, when the English comedians acted in Germany (see "Shakespeare in Germany in the Sixteenth and Seventeenth Centuries," by Albert Cohn—London, 1865), they used in a comedy called "The Turkish Triumph," the following: "Blue body colour and black canvas and fringes, all for the cloud." The company was under the management of one John Spencer. That the late Sir Hubert von Herkomer, M.A.—by the way, a first cousin of mine—was a pioneer in the matter of stage lighting, and even anticipated the Fortuny system, has been acknowledged by many. In the interesting book of Mr. Edwin O. Sachs, "Modern Opera Houses and Theatres" (Batsford), there is a detailed description of his aims and results, as also, of course, in his own book, "My School and My Gospel." But since then, Mr. Gordon Craig—and above all, Max Rheinhardt, who now has a theatre of his own at Berlin—have tried and are utilising every possible device for making the stage productions something marvellous. Houston Stewart Chamberlain says: "Apollo was not only the God of Singing, but also of Light."

In connection with the above I should like to ask: How is it that no illuminating engineer has as yet thought of altering the present lighting system of the concert platform? Solo-performers, and especially we pianists, are at a great disadvantage there. A dreadful glare of light streams on to the white keys of the pianoforte, so that I, for one, can hardly distinguish one key from another, and I am sure my colleagues feel the same. We pianists are "lit up," but only our profiles are lit up, we are not presented at our best. The singer, of course, as also the violinist, has a better chance. They present themselves "full-faced" to the audience, but I do not think it necessary that one need be seen in the full glare of light. R. Wagner's orchestra is heard not seen—I have, however, in my mind something quite new, which some enterprising illuminating engineer and stage-manager might take up.

Colour Music.

We all know that the two senses to which the eye and the ear correspond are: Music and Light. These receive impressions systemising themselves into a work of art. The problem of harmony can here easily be explained and traced, for there is analogy between sound and light, music and colour. Colours do actually suggest musical sounds, and *vice versa*, musical sounds suggest colour.

A psychological affinity by sensitive artists and musicians is indeed felt. The musician speaks of "tone-pictures" (Ton-Gemälde) the artist of "tone" in his paintings. The great colour art analogous to the art of music, should and might be more developed, and it is the art of mobile colour or colour-music which fills the gap. I quote this from a most interesting book on colour music by A. Wallace Rimington (Hutchinson, 1912), to which Sir Hubert von Herkomer has written a preface.

Whistler and others have gone so far as to call their pictorial works "Harmonies," "Nocturnes in Silver and Blue," "Symphonies," etc. The similarity of the action of sound and colour upon us is very great, but of course it requires an educated and sensitive eye

and an artistic mind to create refined and beautiful harmonies in either art.

Since some time I have had in my mind a colour-music pianoforte recital. I would like to play certain pieces by such composers as Chopin, Debussy, Ravel, Schumann, Beethoven, Liszt, Wagner, in which the illuminating engineer would collaborate by doing his share of work in sending forth rhythmic harmonies of light that shall be as music also to the eyes. The following would be our programme :—

First Part.

(1) Bright afternoon ; (2) Sunset ; (3) Twilight ; (4) Moonlight ; (5) Storm arising ; (6) Storm with thunder and lightning.

Second Part.

(7) Early morn ; (8) Sun arising ; (9) Mist and rain ; (10) Clearing up ; (11) Sunshine ; (12) Rainbow.

The scenery on the stage would be : To the left a Roman temple standing on some rocks. A grand pianoforte in the temple, partly hidden, with the performer also partly hidden from view or else placed so that no glare of light would reach him. A lake, and behind, distant hillocks. At right angles some tall trees. The Fortuny horizon would, of course, come in use.

It seems to me that a wonderful combination could be assured if the right artistes could carry this out.

" We might then ' hear ' colour and ' see ' music."

DECORATIVE AND THEATRICAL LIGHTING.

THE close relation between the mood of the audience and the lighting of the stage of a theatre is illustrated by several incidents narrated in a recent paper by Mr. Claude Bragdon before the American Illuminating Engineering Society. At a certain performance of *Macbeth* some members of the audience invariably laughed when the murder of Banquo took place in the forest. Apparently the exact cause of the merriment was not discovered, but it was removed by an alteration in the lighting so as to reveal less of the stage, showing only " the lurking figures of assassins " and creating " a mood of expectancy, curiosity and apprehension." Conversely in one of the scenes of *Hamlet* which is intended to give a touch of lightness and relieve the general air of gloom, the audience could not be induced to laugh until a more cheerful amber-coloured light was substituted for the pallid greenish illumination originally provided. Other instances of light used to supplement the impression created by the acting, for instance a mellow light for the last act of *Cyrano de Bergerac*, where the time is supposed to be autumn, deepening to red in the battle scene. Yet, to be really successful these effects should be so subtle as not to be detected by the audience. A compliment was paid to the expert who arranged the lighting of *Hamlet*, when an artist confessed to him, " You know I forgot to look at the lighting, I got so interested in the play ! "

THE LIGHTING OF CINEMA THEATRES.

ANOTHER recent paper before the American Illuminating Engineering Society, by Messrs. W. B. Ihnen and D. W. Atwater, contains many interesting examples of the special problems met with in lighting scenes for film-production. Each kind of scene requires individual treatment. Fortunately the producer has a valuable weapon in that he can not only modify the lighting but also the nature of surfaces on which it impinges. One of the chief problems is the elimination of incongruous shadows, such as are apt to be cast by the moving figures of actors. We are glad to see that the authors emphasise the need for proper screening and diffusion of light. Another problem arises when it is desired to reproduce in the picture ordinary artificial illuminants, glowing fires on the hearth, etc., which are comparatively inactinic. This has to be solved by the use of special devices.

PRACTICAL ILLUMINATING ENGINEERING.*

By A. L. POWELL.

IN explaining the meaning of "Practical" Illuminating Engineering, Mr. Powell states that the object was to take the completed lamp or lighting appliance developed by the designer and apply it in such a way that the consumer obtained the greatest benefit from it. There seems to be an impression that conditions in other countries are radically different from those existing in America, and that the same methods cannot be applied. Nevertheless, the fundamental principles are the same, and it is only a question of adapting these principles to local conditions. The work may be divided into (A) Educational work, (B) Investigations and Compilations, (C) Experimental and Developmental, and (D) Specific Recommendations. Work on these lines is described as "lighting service."

As regards (A), Mr. Powell mentioned as examples articles on lighting in daily newspapers, material in school text books, talks and demonstrations before school-children, broadcasted radio talks, window displays, demonstrations, handbooks and manuals.

In regard to (B), a distinction must be drawn between work in a research laboratory and the acquirements of data based on actual practice. In the latter field many observations and trials are needed in order to eliminate variables. Some typical cases of such investigations are mentioned. Thus in regard to Light and Safety, useful information was acquired by the illuminating engineer of a large industrial insurance company who went over the records for several preceding years and compiled statistics on the relation of light to accidents. The conclusion was drawn that 18 per cent. of industrial accidents were due to defects in lighting installations. Other investigations have been made on the relation between illumination and industrial production. Many practical tests have been made leading to the conclusion that in general increases in production of the order of 10 per cent., owing to better lighting, can be obtained at an increased cost of lighting of not more than 1 per cent. of the pay-roll.

Similar tests have been made on the relation between the lighting and the "drawing power" of show windows. Thus the number of persons who stopped to look at a window during a given period was noted with illuminations of 15, 40, 65, and 100 foot-candles. 73 per cent. more people stopped to look at 100 foot-candles, than at 15, and proportion at gains were shown at other levels. The use of coloured light for spectacular display increased still further the "drawing power" of windows. It was also found that by strongly illuminating windows on one side of a street traffic could be diverted from the opposite side.

Other interesting researches related to the effect of daylight intensity on station load. A sudden cloud will cause a rapid increase in demand. By keeping a record of daylight intensity and the station load, it was deduced that "psychological darkness," *i.e.*, the point where artificial light begins to be used, occurs at approximately 1,500 foot-candles on a horizontal surface out of doors.

After referring to experiments on the

*Abstract of a paper presented at the meeting of the International Illumination Commission (Geneva, 1924).

inside lighting of motor-buses, and the design of motor-car headlights, Mr. Powell proceeded to discuss residential lighting. Two independent surveys were made by the National Electric Light Association and the Association of Edison Illuminating Companies. In the first case, circulars of enquiry were sent to some 1,500 representative homes. In the second case about 100 men, representing local central station companies, visited each residence with a set of survey forms, foot-candle meter, foot rule and small camera. Amongst other facts that were elicited may be mentioned (1) Only one-half of the homes within easy reach of electric service are wired; (2) the middle-class home is less than half-lighted, and the lower-class home only one-half as well lighted as the middle-class home.

Similar investigations have been made in regard to other classes of service. About 12 years ago some pioneering efforts were made in connection with shop-lighting data being compiled for about 800 premises. A similar survey made about ten years later yielded striking results. It was found that the standard of illumination had been raised 50 per cent.; that the tungsten filament had been almost entirely replaced by the gasfilled lamp, the 200 watt size being used in nearly 60 per cent. of shops visited; that open types of reflectors had been almost largely replaced by enclosed and indirect types of fittings. At the present time figures are being collected over the entire country in regard to the lighting of schools.

In (c), Experimental and Developmental work, attention is drawn to the design of new fittings. Experiments on illuminated signs, and observations of effects in practice have led to the drafting of simple recommendations. A special system of lighting hospital operating theatres has been developed, a feature being the use of 1,000 watt gasfilled lamps equipped with coloured screens to yield "artificial daylight." Experiments have been made with exceptionally high illuminations for show-windows, with the object of eliminating the effect of reflections of bright objects in the glass. Elaborate experiments have been made on the effect of dirt on the output of lighting equipment, and on depreciation of wall finishes. One of the very latest lines of research has been the investigation of the effect of light on plant growth. Laboratory tests are now being supplemented by experiments in commercial greenhouses and out of doors.

Under the heading (D) Specific Recommendations the author mentions that the larger lamp and accessory manufacturers now maintain staffs of competent engineers who are at the disposal of their customers. This is considered a part of the service which is included in the cost of the product. At the request of the purchaser, a lighting layout is made for the factory, office, church, store, residence, etc., and the engineer recommends the system which is, in his judgment, best suited to the user's requirements, regardless of the commercial situation.

In conclusion, a reference is made to the practical work of the Illuminating Engineering Society Committee on Lighting Legislation, and it is recalled that lighting codes for factories have now been adopted in eight States of the Union, as well as the national code.

THE DISTINCTION BETWEEN ILLUMINATION AND BRIGHTNESS.

FOR some time lighting experts have devoted themselves to ascertaining the illumination in foot-candles desirable for various processes, and much progress has been made, though it may be admitted that in some cases authoritative data confirming the values adopted are lacking. However, as is pointed out recently in the *Electrical World*, the ultimate consideration is the *brightness* of the objects viewed. If a surface receiving 10 foot-candles has a reflection coefficient of only 20 per cent., it is in fact only as bright as an ideal white surface would be if it received 2 foot-candles. In many fields of work, for example, in the clothing industries, the need for adjustment of illumination to the quality of material used is recognised. But in many trade processes this is not so. Some people are even disposed to doubt whether, if one substitutes dark cloth reflecting, say, only 10 per cent. for white material reflecting, say, 80 per cent., the illumination must be increased as much as eight times, though they admit that more light is needed. With a very high illumination it seems conceivable that the increase might not have to be inversely proportional to the reflection coefficient. But at moderate illuminations this has been proved to be the case. The classic example was the series of tests conducted at the N.P.L. in connection with the investigations of the Home Office Departmental Committee on Accidents in Workshops, and summarised in the appendix to their First Report (1915). In this experiment the illumination was capable of adjustment, and workers engaged in sewing material were asked to state when the illumination was sufficient. The experiment was then repeated with much darker working material. The results showed fairly conclusively that, in order to obtain comfortable working conditions, the product (Necessary illumination by Coefficient of reflection of material), should be practically constant.

PUBLIC LIGHTING.

In discussions on public lighting it is often pointed out that the main object of the lamps is to illuminate the surface of the road—especially in view of the demands of the congested and rapid traffic of to-day. Experts would now agree that a certain amount of lighting should be allotted to the surfaces of buildings; most of it should be directed downwards, but not everybody will accept this view in practice. It is somewhat strange that it should still be necessary to emphasise this obvious point. In a lecture before the Huddersfield Technical College last November Mr. J. W. Lofts quotes from a book published by the late Mr. William Sugg, in 1871 :—

"The old model street lamps are remarkable for a too abundant illumination of the sky and the opposite effect upon the ground. The shadows of the ribs and iron-work about them are such that, projected over the road, they are exceedingly annoying to drivers of vehicles, while to timid pedestrians they are looked upon as hiding places for thieves. Indeed, as a general rule, a lamp-post surmounted with one of the old pattern lamps may be said to be an excellent strategic point for thieves and roughs."

Accordingly, in a new model, Mr. Sugg replaced the clear glass in the roof by opal glass, the opal serving as a reflector,

and also contrived a neater device than the cumbersome iron cradle, which offered considerable obstruction to the light. In this, as in other matters, Mr. Sugg showed a progressive spirit. But although the art of public lighting has advanced much since then, it is to be feared that there are still many lamps in use which throw an undesirably high component of the light in upward directions.

A NEW USE FOR ULTRA-VIOLET LIGHT.

IN these days we are becoming accustomed to novel applications of ultra-violet rays and their effect for medical treatment is now well authenticated. The experiments described by Messrs. J. S. Hughes and L. F. Payne, in a recent contribution to *Science*, seem to show, however, that their applications are by no means exhausted. These investigations related to the effect of exposure to ultra-violet light on the egg-production of young hens. In the course of sixteen weeks it was found that a dozen pullets treated with ultra-violet light for ten minutes daily laid 497 eggs; whilst a dozen similar birds, eating the same food, but not subjected to the special light-treatment, laid only 124 eggs. The eggs from the former contained more calcium and had twice the percentage of "Hatchability." On reversing the conditions with the two groups of hens confirmatory results were obtained.

We understand that the use of ordinary light from incandescent lamps has proved beneficial in poultry-farming, and we hope shortly to give some account of further experience in this field.

ENGINEERING EDUCATION IN THE UNITED STATES.

WE notice that an investigation of engineering education is being conducted by a committee in the United States, under the direction of Professor W. E. Wickenden, and it is hoped that before long some valuable results will be available. The theory and technique of teaching are being thoroughly surveyed, and the conditions of entry into colleges, duration of courses and other questions are being thoroughly considered. So far, the investigation seems to disprove the impression that engineering education is too technical. On the contrary, it is remarked in the *Electrical World* they are not sufficiently specialised and technical in comparison with the courses prescribed for doctors and lawyers. The possibility of extending the course to five or six years is being seriously considered.

The question is not without interest from the illuminating engineering standpoint. As is well known, the difficulty at present is that, owing to the allocation of time to subjects regarded as indispensable in existing courses, it is extremely difficult to find space for additional instruction in illuminating engineering. Such instruction might, however, well form part of an advanced course taken after students have already received a broad grounding in general engineering and science.

Ultimately, it is to be hoped, the time will come when Illuminating Engineering Departments, dealing comprehensively with all aspects of lighting, will be created at leading technical and engineering institutions.

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REVIEWS OF BOOKS AND PUBLICATIONS RECEIVED.

Transactions of the Illuminating Engineering Society (U.S.A.) (Vol. XIX., November, 1924, No. 9).

The Transactions of the Illluminating Engineering Society (U.S.A.) for November contains the address of the President (Mr. Clarence L. Law), which is largely devoted to education in illuminating engineering. An important step has been the establishment of the Training Course on Lighting, a feature of which is the series of visits to different parts of the United States for the purpose of seeing typical installations and methods pursued by illuminating engineering departments of central stations, etc. The General Secretary's report of the Society's activities is exceptionally comprehensive, and includes a chart showing the membership of the Society since its commencement. A detailed account is also given of the work of the various committees on Progress, Nomenclature and Standards Research, etc. Special interest attaches to the account of the Training Course in Illuminating Engineering. The group of Convention papers deals mainly with decorative and spectacular lighting, and there is also an interesting illustrated account of the artificial lighting of the golf course at Briarcliff, where the Convention was held.

The Journal of the Society of Glass Technology (December, 1924).

This contains several papers on the technicalities of glass-making, including a note by Mr. Francis Buckley on glass houses in Leeds during the 17th, 18th and early 19th centuries. There is the usual informative series of abstracts of recent literature, amongst which we note a paper by Mr. Conrad Beck on the Illumination of Microscope-Fields, and summaries of various recent processes connected with the making of bulbs of electric lamps.

TOPICAL AND INDUSTRIAL SECTION.

[At the request of many of our readers we have extended the space devoted to this Section, and are open to receive for publication particulars of interesting installations, new developments in lamps, fixtures, and all kinds of apparatus connected with illumination.

The contents of these pages, in which is included information supplied by the makers, will, it is hoped, serve as a guide to recent commercial developments, and we welcome the receipt of all *bona-fide* information relating thereto.]

HOLOPHANE ILLUMINATION.

THE second issue of the series of issues of *Holophane Illumination*, the resumption of which we noted in our last issue, is devoted to School Lighting. An introductory article points out the importance of good illumination to the growing child, and other contributions deal with the subject in turn from the standpoint of the hygienist, the architect and the lighting expert. A summary of the code for the lighting of school buildings, approved by the American Engineering Standards Committee, and prepared under the joint sponsorship of the Illuminating Engineering Society (U.S.A.) and the American Institute of Architects is also given. Technical data are dealt with in some detail in a final article, from which the following values of illumination may be quoted: Stairways and corridors, 1-2 foot-candles; assembly halls (not used for study purposes), 2-3 foot-candles; classrooms, libraries, laboratories and rooms devoted to manual training, 3-6 foot-candles; rooms for drawing, sewing and other fine work, 6-15. Thus the order of illumination recommended is considerably in advance of what would have been considered practicable a few years ago. The issue is completed by a representative series of photographs of typical installations, which include elementary schools, public schools, technical colleges, etc.

THE BRITISH INDUSTRIES FAIR.

WE note that the British Industries Fair, to be held in Birmingham during February 16th-27th, 1925, will include the section formerly confined to London. The schedule of exhibits includes lighting, and no doubt, as on former occasions, glassware will be strongly represented.

ELECTRICAL SERVICE.

THE bulletin issued under this title by Electrical Installations, Ltd., lays stress on the fact that this firm maintains a special Lighting Department, and emphasises the need for up-to-date methods in order to obtain efficient results and eliminate eyestrain. Quotations on any electrical scheme will be furnished, and no charge is made for advice. The booklet includes a series of recent installations carried out by the firm, including work at the Bush House, Kingsway, and the Stadium at Wembley.

MAXLUME LIGHTING FITTINGS.

THE "Maxlume" list of industrial lighting fittings published by Veritys, Ltd., as usual, contains a representative series of illustrations of reflectors for industrial use, each illustration being accompanied by a rough indication of the nature of the light distribution and a table comprising essential dimensions and prices, etc. A feature, which we have commented upon in previous editions, is the introductory summary of the chief recommendations in the reports of the Home Office Departmental Committee on lighting in factories and workshops.

A HANDY TABLE LOUD-SPEAKER.

A RECENTLY issued B.T.H. leaflet, giving particulars of radio-equipment, shows one form of loud-speaker made up in a convenient form, the actual apparatus being surrounded by a silk shade, and thus resembling an ordinary portable lamp. Such an apparatus can be placed on a table without appearing unsightly, and appears suitable for drawing-room use.

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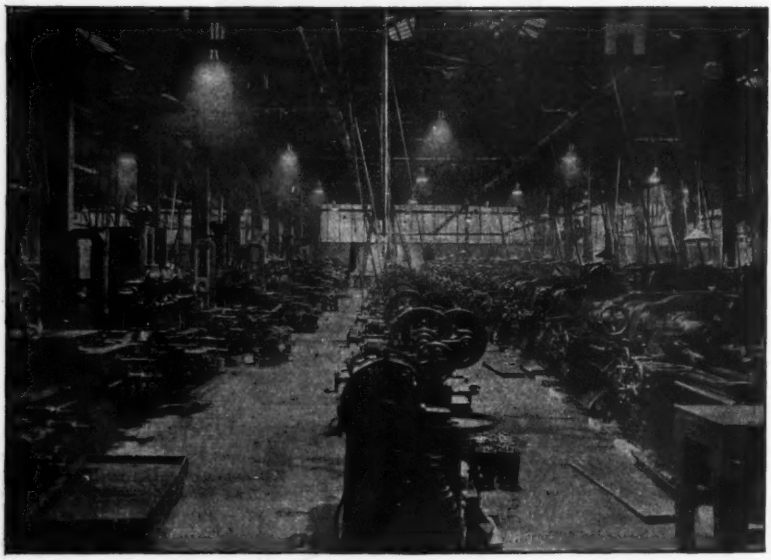

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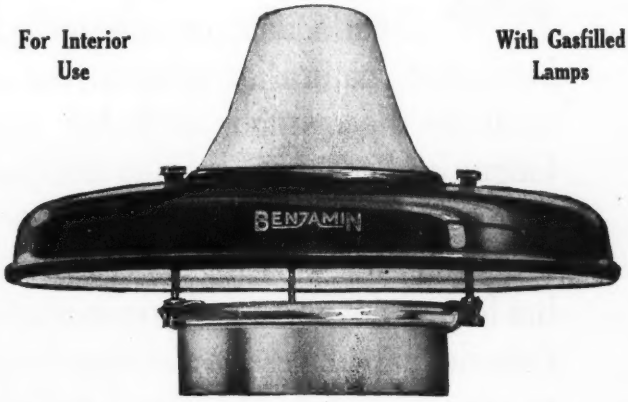

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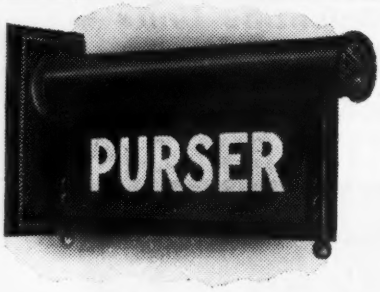

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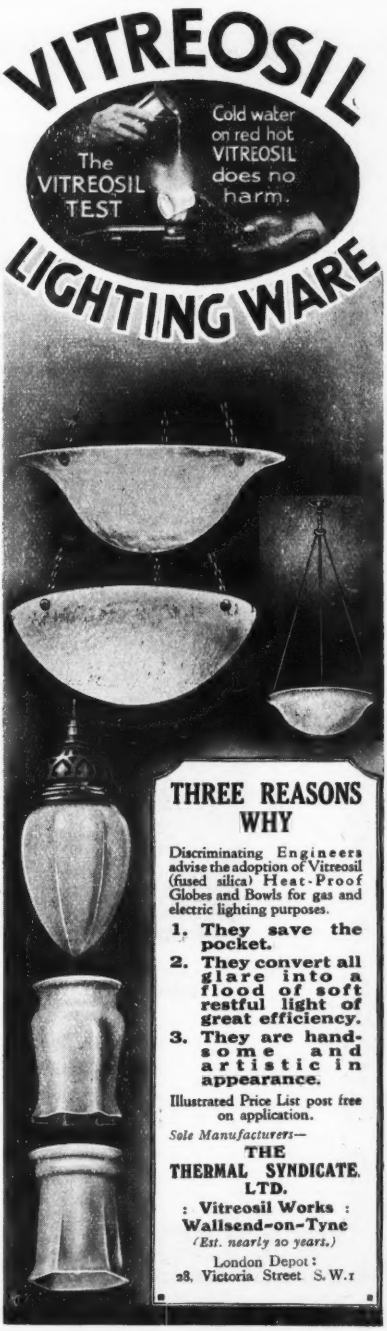
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